10/512100
EV372467714
DT01 Rec'd PCT/PTC 21 OCT 2004

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

APPLICATION FOR LETTERS PATENT

* * * * *

LIGHTING SYSTEM, PARTICULARLY FOR USE IN EXTREME ULTRAVIOLET (EUV) LITHOGRAPHY

* * * * *

INVENTORS

Frank Melzer
Wolfgang Singer

ATTORNEY'S DOCKET NO. LO29-016

C/PRTS

10/512100

PCT/EP03/03616

DT01 Rec'd PCT/PTO 21 OCT 2004

Lighting system, particularly for use in extreme ultraviolet (EUV) lithography

The invention relates to a lighting system, in particular for extreme ultraviolet (EUV) lithography, comprising a projection objective for producing semiconductor elements for wavelengths ≤ 193 nm, a light source, an object plane, an exit pupil, the first optical element having first grid elements for producing optical channels and the second optical element having second grid elements, each optical channel which is formed by one of the first grid elements of the first optical element being assigned a grid element of the second optical element, it being possible for grid elements of the first optical element and of the second optical element to be configured in such a way or arranged in such a way that the result for each optical channel is a continuous beam course from the light source as far as the object plane.

The invention also relates to a projection exposure installation having such a lighting system.

In order to reduce the structure widths of electronic components, in particular of semiconductor components, the wavelength for the light used for the microlithography should be reduced further and further. At present, wavelengths of ≤ 193 nm are already used in lithography.

Here, a lighting system suitable for EUV lithography should illuminate the field predefined for the EUV lithography, in particular the annular field of an objective, homogeneously, that is to say uniformly, with as few reflections as possible. In addition, the pupil of the objective should be illuminated independently of the field as far as a specific filling

level σ, and the exit pupil of the lighting system should lie in the entry pupil of the objective.

With regard to the general prior art, reference is made to US 5,339,346, US 5,737,137, US 5,361,292 and US 5,581,605.

EP 0 939 341 shows a lighting system for the EUV range having a first optical integrator, which has a large number of first grid elements, and a second optical integrator, which has a large number of second grid elements. In this case, the distribution of the illumination in the exit field is controlled via a stop wheel. However, the use of a stop wheel entails considerable light losses. Further solutions proposed, such as a quadrupole illumination distribution and illumination systems that can be used differently via interchangeable optics are, however, firstly very complex and secondly restricted to specific types of illumination.

DE 199 03 807 A1 describes an EUV lighting system which, inter alia, comprises two mirrors having grid elements. Systems of this type are also designated double-facetted EUV lighting systems. The illumination of the exit pupil is in this case determined by the arrangement of the grid elements on the second mirror. The illumination in the exit pupil or an illumination distribution is in this case defined.

In the earlier German patent application 100 53 587.9 a lighting system is described, it being possible for a predefined illumination pattern to be set in the exit pupil of the lighting system by means of appropriate associations between the grid elements of the first and of the second optical element. Using a lighting system of this type, the field in the reticle plane can be

illuminated homogeneously and with a partially filled aperture, and also the exit pupil of the lighting system can be illuminated in a variable manner. The variable setting of any desired illumination distribution in the exit pupil is in this case carried out largely without light losses.

The present invention is based on the object of providing a lighting system with which the basic idea of the earlier patent application can be implemented in practice by means of constructional solutions.

According to the invention, this object is achieved in that the angles of the first grid elements of the first optical element can be adjusted in order to modify a tilt. In addition, the location and/or angle of the second grid elements of the second optical element can also be adjusted individually and independently of one another, in order, by means of displacing and/or tilting the first and second grid elements, to implement a different assignment of the first grid elements of the first optical element to the second grid elements of the second optical element.

By means of appropriate displacement and/or tilting of the grid elements, optical channels in variable configurations can now be achieved.

In order that the individual bundles of rays of field honeycombs as grid elements in the field overlap again, pupil honeycombs as grid elements can be inclined or tilted appropriately in relation to a pupil honeycomb plate or the mirror support of the latter. Mirror facets are particularly suitable as field honeycombs and as pupil honeycombs.

If, in this case, the system is built up as a system

having real intermediate images of the light source after the field honeycomb plate or the mirror support of the first optical element, then the pupil honeycombs can be used at the same time as field lenses for the coupled projection of the light source into the entry pupil of the lithography objective or projection objective.

If, in an advantageous refinement of the invention, the number M of second grid elements (pupil honeycombs) of the pupil honeycomb plate or the mirror support is always greater than N, where N is the number of channels, which is determined by the number of illuminated first grid elements (field honeycombs), variable illumination patterns can be presented in the exit pupil. In other words: in this case, more pupil honeycombs or mirror facets will be provided on the second optical element than would be necessary for the number of optical channels produced by the first grid elements of the first optical element. Given a specific setting with a specific field honeycomb having N channels, in each case only some of the pupil honeycombs are thus illuminated. This therefore leads to segmented or parceled illumination of the pupil honeycombs.

Further advantageous refinements and developments of the invention emerge from the remaining subclaims and from the following exemplary embodiments described in principle by using the drawing, in which:

figure 1 shows a structure of an EUV lighting system having a light source, a lighting system and a projection objective;

figure 2 shows a basic sketch of the beam path having two mirrors with grid elements in the form of

mirror facets and a collector unit;

figure 3 shows a basic sketch of another beam path having two mirrors with grid elements in the form of mirror facets and a collector unit;

figure 4 shows a plan view of the first optical element in the form of a field honeycomb plate (mirror support) having a large number of mirror facets;

figure 5 shows a plan view of the second optical element in the form of a pupil honeycomb plate as mirror support having a large number of mirror facets with circular illumination;

figure 6 shows a plan view of the second optical element in the form of a pupil honeycomb of plate having a large number of mirror facets with annular illumination;

figure 7 shows a plan view of a pupil honeycomb plate;

figure 8 shows a section along the line VIII-VIII from figure 7;

figure 9 shows a plan view of a pupil honeycomb plate which is constructed as a control disk;

figure 10 shows a section along the line X-X from figure 9;

figure 11 shows an enlarged illustration in section of a mirror facet having a solid body joint;

figure 12 shows a plan view of the mirror facet according to figure 11;

figure 13 shows an enlarged illustration in section of a mirror facet having another type of mounting; and

figure 14 shows a plan view of the mirror facet according to figure 13.

Figure 1 shows in a general illustration an EUV projection lighting installation having a complete EUV lighting system comprising a light source 1, for example a laser-plasma, plasma or pinch-plasma source or else another EUV light source, and a projection objective 2 illustrated merely in principle. Apart from the light source 1, there are arranged in the lighting system a collector mirror 2 which, for example, can comprise a plurality of shells arranged in one another, a planar mirror 3 or reflective spectral filter, an aperture stop 4 with an image of the light source (not designated), a first optical element 5 having a large number of facet mirrors 6 (see figures 2 and 3), a second optical element 7 arranged thereafter and having a large number of grid elements 8 in the form of facet mirrors, and two projection mirrors 9a and 9b. The projection mirrors 9a and 9b are used to project the facet mirrors 8 of the second optical element 7 into an entry pupil of the projection objective 2. The reticle 12 can be moved in the y direction as a scanning system. The reticle plane 11 also simultaneously constitutes the object plane.

In order to provide different optical channels for adjusting the setting in the beam path of the lighting system, for example there is a larger number M of mirror facets 8 of the second optical element 7 than corresponds to the number N of the mirror facets 6 of the first optical element 5. In figure 1, the mirror

facets are not illustrated, for reasons of clarity. The angles of the mirror facets 6 of the first optical element 5 can in each case be adjusted individually, while both the angles and the locations of the mirror facets 8 of the second optical element 7 can be adjusted. In figures 7 to 14, explained in the following text, details relating to this are described and illustrated. As a result of the tiltable arrangement and the ability to displace the mirror facets 6 and 8, different beam paths and thus different optical channels can be created between the first optical element 5 and the second optical element 7.

The following projection objective 2 can be constructed as a six-mirror projection objective. A wafer 14 is located on a carrier unit 13 as the object to be exposed.

As a result of the ability to adjust the mirror facets 6 and 8, different settings can be implemented in an exit pupil 15 of the lighting system which, at the same time, forms an entry pupil of the projection objective 2.

In figures 2 and 3, optical channels which are different in principle are illustrated by means of different layers and angles of the mirror facets 6 and 8 of the two optical elements 5 and 7. The lighting system is in this case indicated in simplified form as compared with the illustration in fig. 1 (for example with respect to the position of the optical elements 5 and 7 and with only one projection mirror 9).

In this case, the illustration in figure 2 shows a greater filling factor σ.
For $\sigma = 1.0$, the objective pupil is filled completely; $\sigma = 0.6$ accordingly denotes underfilling.

In figures 2 and 3, the beam path from the light source 1 via the reticle 12 as far as the entry pupil 15 is illustrated.

Figure 4 shows a plan view of a mirror support 16 of the first optical element 5 having a large number of grid elements in the form of mirror facets 6. The illustration shows 142 individually adjustable mirror facets 6 as field honeycombs in rectangular form, which are arranged in blocks in a region illuminated by the nested collector mirror 2. The angles of the mirror facets 6 can in each case be adjusted individually. The facets 8 of the second optical element 7 can additionally be displaced among themselves and, if required, also independently of one another.

Figure 5 shows a plan view of a mirror support 16 or pupil honeycomb plate of the second optical element 7, the optical channels resulting in a circular setting.

Figure 6 shows a plan view of a mirror support 16 of the second optical element 7 having mirror facets in an annular setting. A further possibility consists in a known quadrupole setting (not illustrated). In figures 5 and 6, the illuminated mirror facets are in each case illustrated dark.

Figure 7 shows a plan view of the mirror support 16 of the second optical element 7, the mirror support 16 being formed as a guide disk. The mirror support 16 or the guide disk is provided with a large number of guide grooves (only one guide groove 17 is illustrated in figure 7, for reasons of clarity), in which a circular mirror facet 8 is guided in each case. The guide groove 17 runs essentially radially or in slightly curved form for this purpose. The course of the guide

grooves 17 depends on the respective application and on the desired displacement direction of the mirror facets 8.

Underneath the mirror support 16 or the guide disk, parallel to and resting thereon, there is arranged a control disk 18, which is likewise provided with a number of control grooves 19 corresponding to the guide grooves 17 and therefore to the mirror facets 8. Each mirror facet 8 is thus guided in a guide groove 17 and in a control groove 19. If the control disk 18 is moved in the direction of the arrow 20 in figure 7 by means of a drive device, not illustrated, then the mirror facets 8 are moved radially inward or outward along the guide groove 17. As a result of this displacement, the assignments of the optical channels and therefore the illumination change. This means that, by rotating the control disk 18 relative to the guide disk 16, the associated mirror facet 8 at the point of intersection of the two grooves 17 and 19 is displaced along the associated guide groove 17.

Figures 9 and 10 show a refinement for the displacement of the mirror facets 8 of the second optical element 7 respectively in a guide groove 17 of the mirror support 16, in each case a drive device 21 being provided (illustrated only in principle and dashed in figures 9 and 10). In this case, each mirror facet 8 has its own drive in the associated guide groove 17, it being possible for the drive to be provided, for example, in accordance with the known piezoelectric inch-worm principle.

Of course, for this purpose, other drive devices by means of which the mirror facets 8 can be adjusted individually in each case are also possible. Instead of arranging the drive device in each case directly in

a guide groove 17, if required these can of course also be arranged independently thereof underneath or behind the mirror support 16.

Figures 11 and 12 illustrate in section and in plan view an enlarged illustration of a mirror facet 6 of the first optical element 5, which is connected to the mirror support 16 of the first optical element 5 by a joint 22, which is formed as a solid body joint. In this case, all the parts can be in one piece or each mirror facet 6 has a central web as a joint 22, via which the connection is made to the mirror support 16 located underneath.

By means of actuators 23, not specifically illustrated, which are located between the mirror support 16 and the underside of each mirror facet 6, each mirror facet 6 can be tilted with respect to the mirror support 16. The plan view according to figure 12 reveals that tilting possibilities in both directions are provided by an actuator 23 which is located on the y axis and a further actuator 23 which is located on the x axis. In this case, the two actuators 23 are in each case located on the axis assigned to them outside the point of intersection of the axes.

Since the adjustment or tilting of each mirror facet 6 is carried out only to a very small extent, piezoceramic elements, for example, can be used as actuators 23.

Figures 13 and 14 illustrate a refinement by means of which larger tilts for the mirror facets 6 are made possible. As can be seen from figure 13, in this case there is a central tilting joint or tilting bearing 24 between the mirror facet 6 and the mirror support 16. Here, too, actuators 23 ensure that the mirror facets 6

are tilted both in the x direction and in the y direction. For this purpose, in this case there are two actuators 23 arranged at a distance from each other on the y axis outside the point of intersection of the two axes, and two further actuators 23 outside the y axis on both sides at the same distance from the x axis (see figure 14).

By means of the tilting devices illustrated in figures 11 to 14, it is possible to adjust not only the mirror facets 6 of the first optical element 5 but also the mirror facets 8 of the second optical element 7 as desired and independently of one another.

As distinct from the mirror facets 6 of the first optical element 5, which have an elongated or narrow rectangular form, the mirror facets 8 of the second optical element 7 have a circular form. However, this difference has no influence on the type or mode of action of the tilting devices illustrated in figures 11 to 14.

In principle, the mirror facets 6 of the first optical element can likewise be displaced in the same way as illustrated in figures 7 to 10 but, in practice, this will generally not be necessary; instead, pure tilting adjustments will as a rule be sufficient.

Actuating elements that can be activated magnetically or electrically are also possible as actuators 23. The actuators 23 can in this case adjust the mirror facets 6 and 8 continuously via a control loop (not illustrated). Likewise, it is also possible for the actuators to define end positions, with which in each case two exact tilted positions are predefined for the mirror facets 6 and 8.